Beam Stability at Light Sources – Course Outline
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Monday AM

1. **Introduction** (Decker)

2. **History of Synchrotron Radiation Sources** (Hettel)
   - History of SR development
   - 1st and 2nd generation sources
   - SR experiments
   - Beam stabilizing systems
   - SR flux and brightness
   - 3rd generation sources and improvements
   - 4th generation sources
   - Stability requirement preview

Monday PM

3. **Properties of Synchrotron Radiation** (Decker)
   - Bending magnet SR
     - space-time dependency
     - spectral properties
     - power
     - flux
     - spectral brightness
   - Insertion device SR
     - spectral properties
     - power
     - flux
     - brightness

4. **Essentials of Accelerator Physics** (Decker)

- Single particle equations of motion - transverse
- Basic lattices
- Particle beam phase space
- Betatron tune and phase
- Magnetic deflections and orbit distortion
- Localized orbit bumps
- Single particle equations of motion – longitudinal
- Longitudinal phase space parameters
- Transverse-longitudinal coupling
- Electron beam emittance, propagation of emittance ellipse
- Emittance vs. Courant-Snyder invariant
- Electron beam size and divergence
- Photon emittance and diffraction limit
- Undulator photon properties
- Photon beam dimensions and brightness

Tuesday AM

5. **Time and Frequency Domain Representations** (Decker)

- Time
  - bunch structure
  - time scales
  - instrumentation
- Frequency
  - introduction to sampling and Fourier transforms
    - digital Fourier transform
    - cross-correlation function
    - auto-correlation function
    - Parseval's theorem
  - accelerator characteristic frequencies
  - instrumentation
- Power spectral density
- Betatron and synchrotron oscillations in space and time

Tuesday PM

6. **Beam Stability Requirements for Light Sources** (Hettel)
   - SR beam parameters
   - SR beam line configurations
   - Stability criteria for storage rings
   - SR sensitivity to electron parameters
   - Electron beam properties
   - Stability in phase space
   - Stability time scales and averaging
   - Photon-electron relationships
   - Intensity stability
   - Photon energy stability and resolution
   - Timing and bunch length stability
   - Lifetime
   - Summary of stability requirements for storage rings
   - Stability in linac FELs and ERLs
   - Conclusion

Wednesday AM

7. **Sources of Beam Instability** (Decker)
   - Magnetic
     - field errors
     - quadrupole focusing properties
     - quadrupole misalignment amplification factor
     - beam-based alignment and BPM offset determination
   - Ground motion
     - ground wave propagation properties
     - accelerator/ground motion resonance condition
     - ground motion velocity power spectral density
     - ATL law
   - Magnet/girder motion
   - Gravity – solar/lunar tides
   - Power supplies (correctors)
   - Top-up transients
   - Insertion devices
   - RF system

Wednesday PM

8. **Orbit Correction Principles** (Carwardine)
    - Reasons for orbit correction
    - Orbit deflection from single source
    - Orbit correction techniques
    - Local orbit control
    - Global orbit correction
    - Response matrix
    - Response matrix inversion
    - Selection of BPMs and correctors
    - SVD
    - Least squares matrix inversion – pseudo inverse
    - Weighted least squares inversion
    - Global orbit correction process
    - Orbit correction to orbit feedback
9. **Sampling of Continuous-time Signals** (Carwardine)
    - Sampling theory
    - Aliasing
    - Anti-alias filters
    - Digitizer performance trade-offs
    - Sample-rate conversion (digital down-sampling)
    - Bandpass sampling
    - I/Q detector – analog and digital

Thursday AM

10. **Beam Stability Measurements** (Decker)
    - Charged particle beam pickup electrode types
        - buttons
        - striplines
        - cavity BPMs
    - Analog processing techniques
        - switched-button, narrowband
        - amplitude-phase conversion
        - log-ratio processing
    - Photon beam position monitoring

11. **Systematic Effects** (Decker)
    - RF beam position monitoring
      - intensity dependence
      - fill pattern dependence, top-off effects
      - timing/trigger stability
      - microwave modes in vacuum chambers
      - electronics thermal drift
      - mechanical instability (thermal expansion)
    - X-ray beam position monitoring
    - Vacuum chamber eddy currents

12. **Digital Receivers for BPM Processing** (Sebek)
    - Desired BPM functions
    - Beam signal spectrum
    - Digital receiver
      - principles of operation
      - numerical accuracy
    - SPEAR 3 implementation design
    - Proposed FNAL implementation

Thursday PM

13. **Orbit Feedback Dynamics** (Carwardine)
    - Simple orbit correction algorithm as feedback loop.
    - BPM filtering and processing
    - Corrector dynamics and eddy current effects
    - Regulator design matters
    - Performance metrics for regulator design
    - Orbit feedback system as a noise-shaping filter.
    - Running separate DC and AC feedback systems
    - Impact of different corrector dynamics (leading to a dilemma

Friday AM

14. **Orbit Feedback Implementation** (Carwardine)
    - Digital vs. analog implementation
    - Architectures
    - Reflective memory
    - Reducing global algorithms to many local algorithms
    - APS datapool implementation
    - ID compensation feed-forward
    - Word length and quantization effects
    - Real-time data analysis
    - Orbit motion source identification

15. **Introduction to Multibunch Instabilities and Feedback** (Sereno)
    - Coupled bunch modes
    - Wakefields and impedance
    - Types of instabilities
    - Longitudinal coupled bunch modes
    - Robinson instability
    - Transverse coupled bunch modes
    - Options for eliminating multibunch instabilities
    - Landau damping
    - Feedback systems
    - Suppression of closed orbit for feedback systems
    - Bunch-by-bunch and mode-by-mode feedback

Friday PM

16. **Review of Problem Sets**